California Global Warming Solutions Act of 2006

Cement Technical Team

Focused Meeting to Discuss Mandatory Greenhouse Gas Emissions Reporting Concepts

May 9, 2007
Sacramento, CA
Cal/EPA Headquarters

Cement Technical Team Meeting Overview

- Overview of April 11, 2007 Meeting
- 1990 Statewide GHG Inventory for Cement Production
- Mandatory Reporting
- Direct Process CO_2 Emissions
- Stationary Combustion GHG Emissions
- Mobile Combustion
- Fugitive Emissions
- Cement GHG Emissions Verification
- Additional Stakeholder Comments
- Next Steps and Schedule

Overview of April 11, 2007 Meeting

Cement Technical Team Meeting: April 11, 2007

- Action Items
- Mandatory GHG Emissions Reporting: Cement Plants
- GHG Emission Estimation Methods
- Current Inventory
- Cement GHG Emissions Verification

April 11, 2007 Meeting Action Items

- Calculate GHG Emissions Using Mass-balance Approach
- One methodology acceptable for each source
  - Direct Process-Related Emissions
    - Clinker-Based Approach
    - CSI Protocol
    - Plant Specific Data
  - Direct GHG Emissions
    - Mobile Sources – Annual Fuel Consumption
    - Stationary Combustion – Fuel Use
    - Fugitive Sources – Storage of Fuels
  - Indirect Emissions
    - Purchased Electricity Heat/Steam – Annual Usage
- Technical Team Support of Current Inventory Calculations
- Further Discussion of Verification

1990 Statewide GHG Inventory for Cement Production

Statewide GHG Emissions Level

AB32 requires the Air Resources Board to:

- Determine 1990 statewide emissions level
- Consider all six Kyoto gases
- Establish 2020 limit equivalent to 1990 level
- Use best available data
- Present for ARB Board consideration by January 1, 2008

Improving Existing Estimate of 1990 Statewide Emissions Level

- Begin with existing state GHG inventory from California Energy Commission (CEC)
- Document existing data sources and emissions estimation methods
- Acquire improved data for selected source categories
- Establish new 1990 statewide, aggregate GHG emissions level

Methodology for Estimating Statewide Cement Process Emissions

Process CO_2 emissions = Cli x (CaO x MWR) x CKD

Where:

Cli = State clinker production data (thousand metric tons) *

CaO = Lime percent content of the clinker (.65) **

MWR = Molecular Weight Ratio of CO2 to CaO (.785) ***

CKD = Cement kiln dust correction factor (1.02) ****

* Statewide clinker production data (U.S. Geological Survey)

** Percent Lime factor (IPCC - *Good Practices Guidance*)

*** 44g (CO2) / 56g (CaO) – Molecular Weight Ratio

**** CKD correction factor (IPCC - *Good Practices Guidance*)

Note: This is the same equation used in the current GHG inventory with updated activity data from USGS

Existing 1990 Emissions Estimate for Cement Production

- Existing California Energy Commission estimate of emissions

Combined Process and Stationary Combustion:

4.62 MMTCO2 Eq. from calcination

0.18 MMTCO2 Eq. from natural gas combustion

0.00 MMTCO2 Eq. from petroleum coke

2.50 MMTCO2 Eq. from coal combustion (estimated)

Total 7.30 MMTCO2 Eq. in 1990

Updated 1990 Emissions Estimate for Cement Production

- Improved 1990 estimates based on best available data

Combined Process and Stationary Combustion:

5.10 MMTCO2 Eq. from calcination *

0.18 MMTCO2 Eq. from natural gas combustion

0.00 MMTCO2 Eq. from petroleum coke

2.50 MMTCO2 Eq. from coal combustion (estimated)

Total 7.78 MMTCO2 Eq. in 1990

*** Updated Clinker Production data from USGS**

Comparison of Currently Available Data Sources

- Clinker production data is necessary for process CO2 emissions calculation
- Statewide clinker production data options for 1990:
  - U.S. Geological Survey (USGS)
  - Portland Cement Association (PCA)
- Difference between USGS and PCA provided clinker data for 1990?
  - USGS data is approximately 7% higher than PCA data
  - USGS clinker production data based on actual cement plant data with no estimates

Mandatory Reporting

Mandatory Reporting

- Accurate Accounting
- Major Sources and Sectors
- Facility-Level Reporting
  - Process-Related Emissions
  - Stationary Combustion
  - ARB Still Considering Other Point Sources
    - GHG Emissions Intrinsic to Process
- Regulation defines major sources to report

Direct Process CO_2 Emissions

Direct Process CO_2 Emissions

- Registry/CSI Clinker-Based Methodology
- Clinker Emission Factor
  - Define Carbonate Feed
- CKD Emission Factor
  - CKD Calcination Rate
- Organic Carbon in Raw Materials
  - Default Value
  - Plant-Specific Emissions

Direct Process CO_2 Emissions: Clinker-Based Methodology

California Climate Action Registry/CSI Equation

Process CO_2 emissions = [(Cli) (EF_{Cli}) + (CKD) (EF_{CKD})]

Where:

- **Cli = Quantity of clinker produced**
- **EF_{Cli} = Clinker emission factor**
- **CKD = Quantity CKD discarded**
- **EF_{CKD} = CKD emission factor**

Clinker Emission Factor: Activity Data

Clinker produced	Mass
CaO content of clinker	% Range= 60-67%
MgO content of clinker	% Range= 1-6%
Non-carbonate CaO	Mass
Non-carbonate MgO	Mass

EF_{Cli} = [(CaO content – non-carbonate CaO) • Molecular ratio of CO_2/CaO]
+ [(MgO content – non-carbonate MgO) • Molecular ratio of CO_2/MgO]

Clinker Emission Factor: Plant-Specific Calculation

EFCli = [(CaO content – non-carbonate CaO) • Molecular ratio of CO2/CaO]
+ [(MgO content – non-carbonate MgO) • Molecular ratio of CO2/MgO]

Where:

CaO Content = 65%

Molecular Ratio of CO_2/CaO = 44g/56g = 0.785

MgO Content = 1%

Molecular Ratio of CO_2/MgO = 44g/40g = 1.092

EF_{Cli} = [0.65 • 0.785] + [0.01 • 1.092] =
= [0.51025 metric tons CO_2 • 1,016 kg/metric ton]
+ [0.01092 metric tons CO_2 • 1,016 kg/metric ton]
= 518.44 kg + 11.10 kg = 530 kg CO_2/metric ton clinker

Clinker Emission Factor: Non-Carbonate Feed Definition

- Added as Raw Meal to the Kiln
- Measured by Thermo-Gravimetric Methods
- Non-Carbonate CaO
  - Calcium Silicates
  - Coal ash
    - Incineration residue
    - Dust collectors
  - Steel slag or fly ash
- Non-Carbonate MgO

Cement Kiln Dust (CKD) Emission Estimates

- Portland Cement Association Survey
- All 11 Cement Plants Responded
- 2 Plants Disposing of CKD

Year	CKD Removed for Beneficial Use	CKD Removed for Disposal	Total CKD Not Recycled to the Kiln
2005	74,515 metric tons	82,111 metric tons	156,626 metric tons

CKD Emissions Estimates

Registry/CSI Protocol	
Equation Inputs	1. CKD Discarded 2. CKD Emission Factor
CKD Emission Factor Equation	$EF_{CKD} = \dfrac{\dfrac{EF_{Cli}}{1+EF_{Cli}} \times d}{1-\dfrac{EF_{Cli}}{1+EF_{Cli}} \times d}$
Where	EF_{Cli}=Clinker Emission Factor d = CKD calcination rate

CKD Calcination Rate

- Where d=1
- 100% Calcination Rate - CSI
- Overstatement of CKD Emissions
- Lower Calcination Rate
- Influences CKD Emission Factor

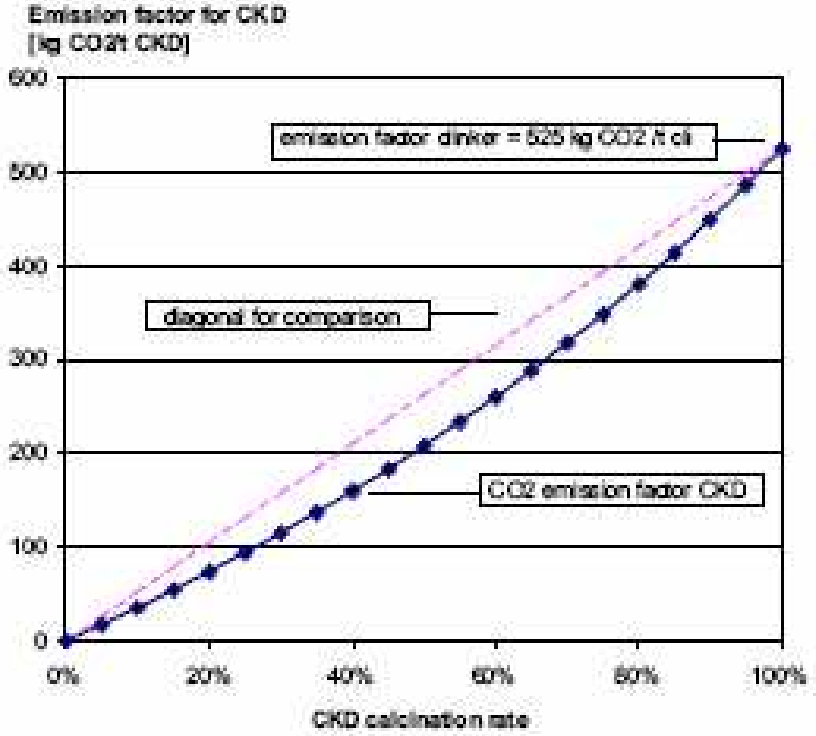

Figure A4-1: Influence of CKD calcination rate on the CO_2 emission factor for CKD, using the default dinker emission factor (525 kg CO_2/t cli) as an example.

CKD Calcination Rate

Plant-Specific Equation

$$d = 1 - \frac{fCO2_{CKD} x (1 - fCO2_{RM})}{(1 - fCO2_{CKD}) x fCO2_{RM}}$$

Where:

$fCO2_{CKD}$ = weight fraction of carbonate CO_2 in the CKD

$fCO2_{RM}$ = weight fraction of carbonate CO_2 in the raw meal

Source: Cement Sustainability Initiative

CKD Calcination Rate

- 100% or 50% (IPCC) Calcination Rate
- Other Calcination Rate
- Plant-Specific CKD Emission Factor
- Cement Sustainability Initiative Equation
- Weight fractions of carbonate CO_2
  - CKD and Raw Meal
- Measured by Chemical Analysis
- Loss on Ignition Test or Titration

Direct Process CO_2 Emissions: Organic Carbon in Raw Materials

CO_2 emissions from TOC in raw materials =

$$(TOC_{R.M.})\ (R.M.)\ (3.664)$$

Where:

$TOC_{R.M.}$	=	Organic carbon content of raw material (%)
R.M.	=	The amount of raw material consumed (t/yr)
3.664	=	The CO_2 to C molar ratio

Organic Carbon in Raw Materials

- Plants Consuming Shale or Fly Ash AND
- Plants Generating CKD
  - $TOC_{R.M.}$ Varies Substantially
  - Plant-Specific Data to Calculate $TOC_{R.M}$
- Other Plants
  - Default Value for Reporting
  - Provide Amount of Raw Material Consumed
  - Self-Calculating Mechanism in Reporting Tool

Direct Process Emissions: Organic Carbon in Raw Materials

CO_2 emissions from TOC in raw materials =

$$(TOC_{R.M.})\ (R.M.)\ (3.664)$$

Where:

- $TOC_{R.M.}$ = 0.2 % Default
- R.M. = Plant X consumes 1.9 MMT raw material per year
- 3.664 = The CO_2 to C molar ratio

CO_2 emissions from TOC in raw materials =
13,923 metric tons CO_2
(2% of CO_2 Emission Estimate)

Stationary Combustion GHG Emissions

Stationary Source GHG Emissions

- GHG Emissions Estimates
  - All Three Pollutants
  - Other Fuel Sources
- Default Emission Factors
- Fuel-Specific Emission Factors
- Biomass
- Co-generation

Stationary Source GHG Emissions: Fuel Use Calculation

- Cement Kilns
- Non-Cement Kiln Units
- Quantity and Type of Fuel
  - Default Emission Factors
  - Plant-Specific Emission Factors
- Report Conventional and Alternative Fuels
- CO_2, CH_4, and N_2O

Stationary CO_2 Emissions: Coal Fuel Use

Total CO_2 Emissions (metric tons) = Total Annual Fuel Consumed (MM Btu) • Emission Factor (kg CO_2/ MM Btu) • 0.001 (metric tons/kg)

Example: COAL CO_2 Emissions

3,600,000 MM Btu x 93.72 kg CO_2/MM Btu X 0.001 metric tons/kg

Total CO_2 Emissions = **337,392 metric tons CO_2**

Stationary CH_4 Emissions: Coal Fuel Use

Total CH_4 Emissions (metric tons) = Total Annual Fuel Consumed (MM Btu) • Emission Factor (kg CH_4/ MM Btu) • 0.001 (metric tons/kg)

Example: COAL NH_4 Emissions

3,600,000 MM Btu x 0.0111 kg CH_4/MM Btu X 0.001 metric tons/kg

Total CH_4 Emissions = **39.96 metric tons CH_4**

Calculator will convert to CO_2e

Stationary N_2O Emissions: Coal Fuel Use

Total N_2O Emissions (metric tons) = Total Annual Fuel Consumed (MM Btu) • Emission Factor (kg N_2O/ MM Btu) • 0.001 (metric tons/kg)

Example: COAL N_2O Emissions

3,600,000 MM Btu x 0.0016 kg N_2O/MM Btu X 0.001 metric tons/kg

Total N_2O Emissions = **5.76 metric tons N_2O**

Calculator will convert to CO_2e

Total Stationary CO_2e Emissions: Coal Fuel Use

GHG	Emissions (metric tons)	GWP	CO_2e Emissions (metric tons)
CO_2	337,392	1	337,392
CH_4	39.96	21	839
N_2O	5.76	310	1,786
Total CO_2e Emissions			340,017

Stationary Combustion Emission Factors

- Default Values
  - "Higher" Heating Value (HHV) – U.S.
  - "Lower" Heating Value (LHV) – International
- Fuel-Specific Emission Factors
  - Major Fuel Sources
  - Measure Heat Content of Fuel
  - Assess Carbon Content
  - Frequency of Monitoring
    - Part 75 – Weekly Measurement

Stationary Combustion Biomass Emissions

- Biomass Fuels
  - Wood
  - Non-Impregnated Saw Dust
  - Agricultural Residue
  - Paper
  - Dried Sewage Sludge
- Biomass Reporting
  - Power/Utility Protocol Guidance
  - Default Emission Factors
  - Biomass Category

Stationary Combustion
Co-generation at Cement Plants

- Calculation in GRP
- Ownership Patterns
  - Joint Agreements
- Boundary Questions
  - Operational Control
- Power/Utility Discussion Group
- More Discussion

Mobile Combustion GHG Emissions

Mobile Emissions

- Definition
  - Report GHG Emissions from On-site Sources
    - Off-Road Quarry Vehicles
    - Mobile Quarry Equipment
    - Heavy Duty Vehicles
      - Trucks
      - Trains
    - Other Mobile Combustion Devices
    - Exclude Light-Duty Vehicles that Purchase Fuel Off-Site
- Confirm Recommendation
- ARB Consideration

Fugitive
GHG Emissions

Fugitive Emissions: Coal Fuel Storage

- Methane Emissions from Fuel Storage
- Underground versus Surface Mined Coal
- Typical California Coal
  - Bituminous
  - Lignite
  - Sub bituminous
- ARB Mandatory Reporting

Cement GHG Emissions Verification

Verification

- ARB still considering verification options
  - Third Party
  - ARB Review
  - Self Verification
- Calculation complexity varies by industry
- Cement industry verification experiences

Additional Stakeholder Comments

Next Steps and Schedule

Next Steps and Schedule

- Informal Written Comments
  - May 15, 2007
- Public Workshop
  - May 23, 2007
- Staff Report in October
- Board Hearing in December
- THANK YOU!

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GHG Mandatory Reporting Website
http://www.arb.ca.gov/cc/ccei/ccei.htm

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